

Historical Information

H.4 Pre-Event Reports

Book 1

Project Rulison: Pre-Shot Predictions of Structural Effects

HPR 2

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**PROJECT RULISON:
Pre-Shot Predictions
of Structural Effects**

John A. Blume & Associates
Research Division
San Francisco, California

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PROJECT RULISON: PRE-SHOT PREDICTIONS
OF STRUCTURAL EFFECTS

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ABSTRACT

This report includes results of pre-RULISON structural response investigations and a preliminary evaluation of hazards associated with ground motion effects on buildings, reservoirs, and earth structures. Total damage repair costs from an engineering judgment prediction are provided. Spectral Matrix Method calculations are now in progress. Also included are general safety recommendations.

A summary of predictions follows:

Structural Response

Damaging motions are probable in the region inside 25 kilometers. Structural hazards exist in Grand Valley, at the Anvil Points Research Station, and at various small ranches out to a distance of 14 kilometers from Ground Zero (GZ). The area is much more densely populated than would appear from initial project information.

Earth Structure Hazards

Rockfall and hazards to slope stability create major problems. Structures, highways, railroads and water courses may suffer extensive damage as a consequence. Snow slides may also be a problem if deep wet snow cover still persists at shot time.

Reservoirs and Water Supplies

The Harvey Gap dam above Silt presents a serious hazard because of its age and general disrepair. The reservoir is nearly full and will be spilling soon after thaws begin. The spillway over the dam crest and the outlet works are in extremely poor condition.

Local residents are very much concerned about any possible damage to local water supplies which are vital to the habitability and livelihood of those areas.

Damage Cost Prediction

A preliminary engineering judgment estimate of damage costs, based on current Environmental Research Corporation response spectra predictions totals about \$130,000. Results from the Spectral Matrix Method prediction are being calculated.

Safety Precautions and Evacuation Recommendations

Area evacuation is recommended for the region out to 8 kilometers from Ground Zero and for Grand Valley. Temporary evacuation of the Anvil Points Research Station, the Union Carbide plant east of Rifle, at small ranches out to a distance of 14 kilometers from GZ, and selected structures in Rifle and Collbran is recommended. Evacuation of the TOSCO facility is also recommended because of rock fall hazard. Particular concern has been expressed for the deteriorated Harvey Gap Dam and unless further study discloses otherwise, recommendations for downstream evacuation may be necessary, including the town of Silt.

Some sections of major roads and highways, and some creek valleys are suggested for closure, as detailed in the following text. It is further suggested for consideration that the rock fall and landslide hazard could be reduced by rescheduling the event for mid-summer, because of the increased stability of slopes during the dry early summer months.

SUMMARY

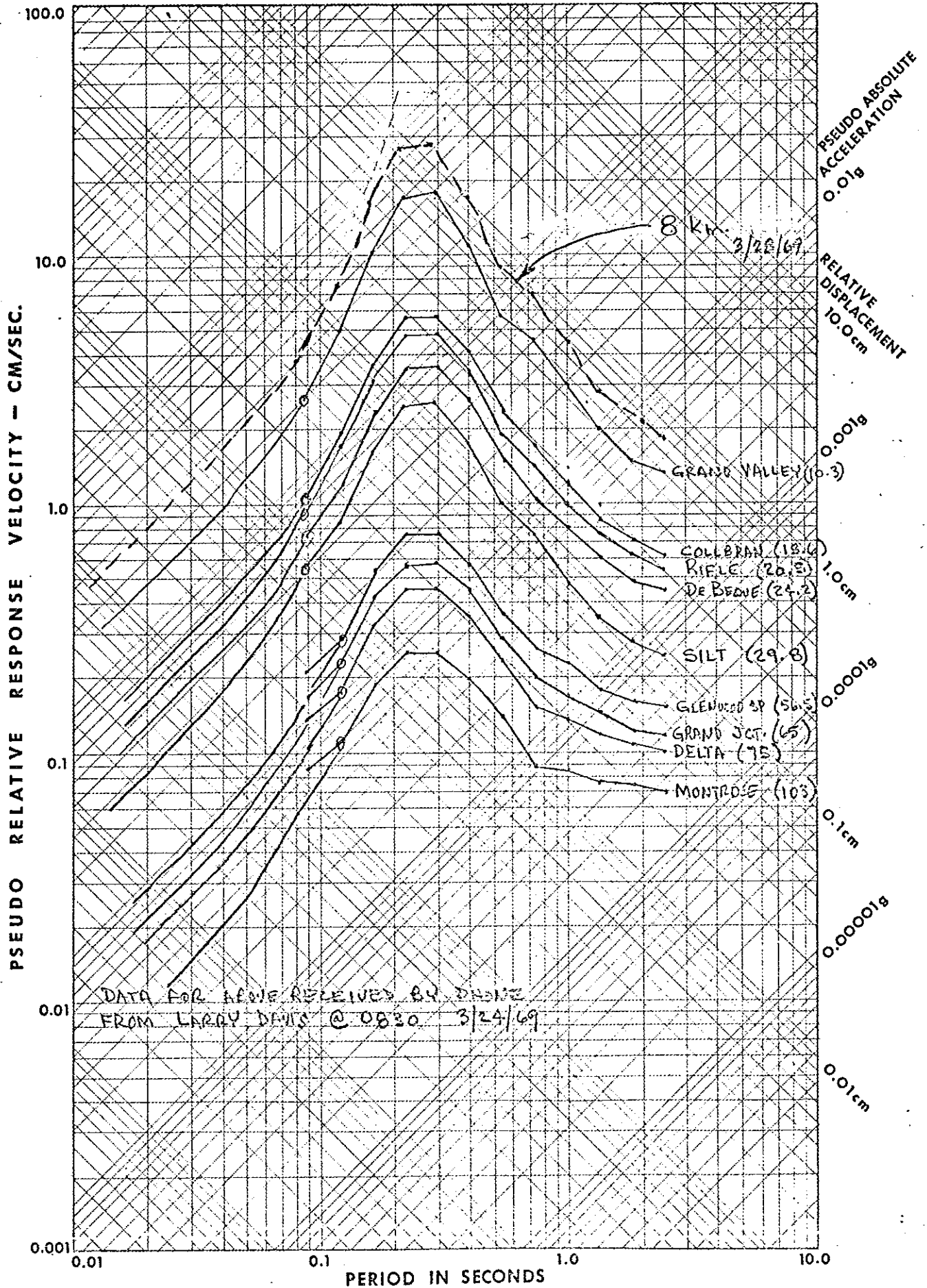
This report presents a preliminary evaluation of structural response hazards and earth structure hazards associated with the RULISON event presently scheduled for late May 1969. The evaluation is based on field and office studies in progress since late January of this year. The report contains damage predictions and safety recommendations, based on current Environmental Research Corporation predictions of peak ground motion and response spectra (Fig. 1).

An engineering judgment estimate of damage costs totals \$129,300 based on the spectra referred to above.

Serious damage is predicted inside 8 kilometers of Ground Zero (GZ) and evacuation for the duration of the shot period in these areas is recommended. Temporary evacuation is recommended for Grand Valley, small ranches out to 14 km, the Anvil Points Research Facility, the TOSCO facility, the Union Carbide plant east of Rifle, and for selected structures in Rifle and Collbran. Some sections of highways, railroads, and creek valleys are also recommended for temporary closure because of rock fall and slope failure hazards.

Particular concern is expressed for the Harvey Gap Dam above Silt because of its age, disrepair, and the current probability that it will be spilling very early in the spring thaw. Spillways and outlet works are badly deteriorated. This dam is a hazard at present, and will be an aggravated hazard under seismic ground motion. Unless remedial measures are taken prior to shot time, or additional studies prove the safety of the dam under dynamic loading we would recommend evacuation of the valley downstream from this dam. This may involve the town of Silt.

Other particular problems are possible effects on water supplies. Water is a critical commodity in the area and much concern is expressed by local residents on this aspect. We are including a sampling of locations with cisterns in our condition survey planning.



ERC PREDICTIONS OF 5% DAMPED PSRV
BASED ON MAX. YIELD 60 kt.

RULISON

FIG 1

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INTRODUCTION

The RULISON event is a planned 40-kiloton (kt) nuclear detonation at a depth of about 8400 feet in Garfield County of western Colorado (see map, back cover pocket), approximately at latitude 39°24' North, longitude 107°56'30" West. The maximum credible yield and the one on which response predictions, estimates, and recommendations are based is 60 kt. The shot is currently scheduled for late May, 1969.

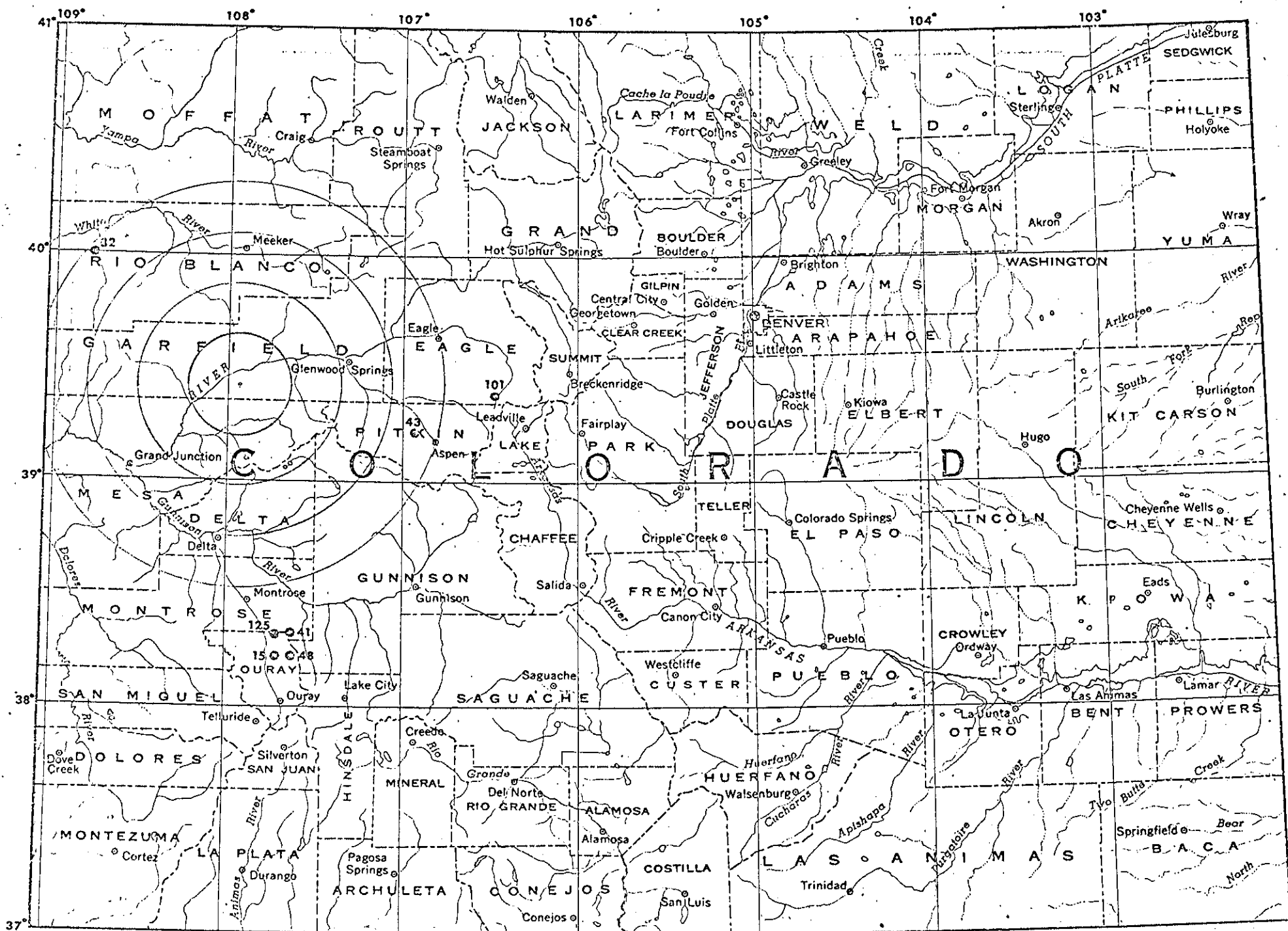
John A. Blume & Associates Research Division, under contract with the Nevada Operations Office of the U.S. Atomic Energy Commission, has been assigned responsibility for structural inventories in the range of probable damage, structural response and damage predictions, surface earth structure hazard evaluations, and recommendations for safety measures in these particular aspects. The predictions are based on field data, office studies, ground motion predictions from the Environmental Research Corporation (ERC), and pertinent published information.

A companion report, JAB-99-60, Project RULISON: Inventory of Structures, presents compilations of data on structures and reservoirs within range of possible damage from the proposed event. Preliminary versions of these two reports were submitted to the Effects Evaluation Division, NV00, on March 15, 1969.

SEISMICITY

A brief study of the seismic exposure of the area is presented in this report. These data have been abstracted from a more detailed tabulation of earthquake epicenters which is included in JAB-99-60.

DATE	EPICENTER Lat - Long.		MOD.MER. INTEN.	MAGNI- TUDE	DEPTH (km)	MAP NO.	OBSERVATIONS
	N	W					
11-11-13	38.2	107.7	V			15	Strong at Montrose, Ouray and Telluride. (7,500 sq. mi.).
8-8-44	-	-	VI				Montrose area (3,000 sq. mi).
1-17-50	40.5	110.5	V			29	Strong at Grand Junction. Buildings shaken, plaster cracked. Epicenter in Utah.
2-21-54	40.0	108.75	IV			32	Felt in Grand Junction and adjacent towns.
10-11-60	38.3	107.6	VI	5.5		41	Intensity IV at Grand Junction, I to III at De Beque. (10,000 sq. mi.).
10-17-60	39.2	106.9	V			43	Aspen. Objects fell from shelves.
2-5-62	38.2	107.6	V			48	Slight damage in Cimarron. Felt in Montrose and Ridgway.
8-30-62	41.8	111.8	VII			56	Intensity IV at Rangely, Mack and Clifton, I to III at Grand Junction, Cameo, Fruita. (65,000 sq. mi.) Epicenter in Utah.
4-3-66	39.36	106.46		4.7		101	315-ton chemical explosion at dam site by Bechtel Corp.
4-14-67	38.3	107.7		4.5	33	125	



STRUCTURAL HAZARD EVALUATION

Rulison Farms

Within a radius of 8 kilometers from ground zero (GZ) are the Rulison farms and many small cabins and isolated structures. Due to the heavy snowpack in this area we have been unable to visit all structures by automobile. Observation has therefore been conducted by light aircraft and aerial photos. Generally the structures are of wood frame construction with a few masonry buildings noted. In the Rulison farm area our inventory notes five two-story homes with a value of \$80,000 and many other one-story buildings. Of 100 structures noted, 73 were wood, 5 were concrete block, 2 were brick masonry and 20 were log buildings. The Denver and Rio Grande Railroad reports their microwave installation on North Mamm Peak, about 7.5 kilometers easterly of GZ; however aerial reconnaissance has failed to disclose the presence of a tower with dish antennae in the area of North Mamm Peak. The exact location has been requested from the owners. A D&RG RR microwave tower and a Forest Service repeater station were sighted on Service Point about 20 km southeast of GZ. Total structure value within the 8-kilometer radius of GZ is presently estimated at \$200,000.

Ground motion in the area is estimated to be in excess of 0.3g with spectral response for structures of 0.2 second period estimated at 0.8g based on ERC-predicted spectra. At these levels of motion some slight shifting on foundations could occur. Damage to chimneys could also occur as a result of differential motion or banging of the chimney against the house. Other damage could occur to bric-a-brac, standing objects such as a grandfathers clock and to hanging mirrors and pictures. Bracing measures and some chimney removal for specific structures may be recommended following conclusion of our structural inventory and condition survey. It is recommended that all bric-a-brac and other vulnerable objects be removed to a safe status.

Grand Valley

The town of Grand Valley is located 10 kilometers northwest of GZ. The population of the town is estimated at 200 with an equal number located in the rural areas northerly and southerly of the town.

There are approximately 500 structures ranging from small sheds to residences to two-story commercial buildings in the town with an estimated value of \$600,000. The structures in the commercial area are generally old brick 1 and 2-story buildings and are partially unoccupied. The largest structure is the school which is constructed of yellow brick with a red brick addition. There are a few brick veneer houses and the rest are of all wood construction.

There are two through-truss bridges of rather light construction located at the Grand Valley and Rulison crossings of the Colorado River. It is not anticipated that these structures would fail of themselves under the seismic loading predicted since the bridges are constantly subjected to dynamic loadings. The bridge seats should be looked at to determine their ability to resist horizontal motion. Abutments appear to be cracked in spots.

The spectral prediction for Grand Valley is 0.5g for structures with a period of 0.2 seconds and ground motion is estimated at 0.2g. Under these conditions only moderate damage is anticipated, mostly in the older two-story commercial structures. Bridge abutments at the Grand Valley and Rulison bridges will be analyzed for lateral resistance; however, they are expected to be adequate for the maximum yield spectral motions.

Anvil Points Research Station

This facility was built in 1945 by the Bureau of Mines as an experimental research center. It is now in a mothballed condition.

Just below the plant is the housing area where there are some 79 wood frame residential structures. The plant has several concrete block warehouse buildings, a 2-1/2 story administration building and several metal covered buildings. In addition to the crusher plant and retort structures, there is a cracking tower, several guyed stacks and many large steel petroleum tanks. Near the highway there is a large transformer substation and a pumping plant. The housing area has an estimated value of \$800,000 and the plant is assumed to be valued at \$3.5 million.

Spectral acceleration for the tower and retort structures is predicted to be approximately 0.5g and some slight overstressing may be noted in bracing members and anchor bolts and foundations. Storage tanks may spill over due to liquid motion if full. Failure of tower structures is not anticipated but all anchor bolts and guy wires should be checked for tightness and adequacy. Some extension of existing cracks may be noted in the concrete block warehouse structures, the stuccoed administration building and the residential structures.

The oil shale mines near the top of the mesa and above the plant were inaccessible and therefore not inspected. These mines are the responsibility of other agencies. Conversation with Mr. Malcolm Smith, Supt. of the maintenance crew, disclosed that Mr. Smith plans to open all doors in the mine to allow free flow of air and lessen the chance of concussion damage in the event of any mine collapse.

Microwave Tower

A microwave installation was noted at about 14 kilometers northwest of GZ. This installation, assumed to be by Mountain States Telephone Company, consists of two dish type antennae mounted on a square tower. It is situated halfway up the slope to the mesa and was inaccessible due to the snow; observations were made with binoculars. A generator shack usually is a part of such an installation although no buildings were visible. Estimated value is about \$50,000.

While spectral acceleration is predicted to be relatively high, damage to the structures is not felt to be probable since these facilities are usually designed for high wind and snow loadings which usually govern.

Ranches

There are many ranches to the south of GZ at an average range of 14-18 kilometers surrounding GZ. These ranches are generally of wood construction and a few ranch houses in the area near Collbran were noted to have brick veneer exteriors. Several of the ranches were unoccupied and may possibly be used as summer ranch quarters only. Value of the ranch structures is assumed to be \$100,000 based on incomplete reconnaissance.

Union Carbide Plant

This plant, located 1.5 miles east of Rifle, processes vanadium and uranium ore. Among the important structures are the 200,000-gallon water tank elevated 100 feet above ground, the 360 ft. long x 9 ft. diameter kiln, the wood stave tanks with diameters varying from 36 feet to 60 feet and 12 feet to 20 feet high and the large concrete block walled -- steel framed process buildings. The facility operates on a continual basis.

Spectral accelerations in the 0.2 to 0.3 second period range are predicted to be about 18% g and ground motion is predicted at about 7% g or less. At these levels some minor additional cracking of the concrete block filler walls of the process buildings is possible. Other features of the plant should respond well and minor damage such as slight overstressing of bolted connections is possible. Spillage of acid due to sloshing of tanks is also possible. Further analysis of plant structures is in process and additional recommendations may be made.

A mill tailings pile composed of silt size particles and a settlement pond which is retained in a fully saturated condition behind

earth embankments is located adjacent to the plant. A possible hazard exists in the tendency for saturated silty material to liquefy under dynamic load. This hazard is being analyzed and additional recommendations will be made as necessary.

Collbran

Collbran and its small suburb of Plateau City is the center of an agricultural community. There is a large one-story brick school in Plateau City of recent construction, a Civilian Conservancy Corps camp with many permanent buildings as well as trailers, and the commercial section with several older concrete block and brick buildings in generally fair condition. Residential structures are generally wood frame with many two-story homes in evidence.

Ground motion at this range is predicted to be less than 7% g. Minor damage such as cracking of interior plaster and extension of concrete block cracks is possible.

Rifle

This is the largest town close to GZ with a population of 2,135. The commercial district and many of the homes are situated in the valley and some of the newer homes have been built on the terrace above the town. Commercial structures are generally of brick two-story construction. Homes are wood with a small amount of brick veneer noted.

Motion at Rifle will be fairly high and minor damage such as extension of cracks is possible.

De Beque

The town of De Beque has a population of 173 and about 300 buildings ranging from small wood structures to wood frame homes to two-story brick commercial buildings. The town is generally owned

by Gulf Oil. Many of the two-story structures are not in use and appear to be abandoned such as the old two-story brick De Beque High School and the IOOF Meeting Hall. The newest structure is the one-story concrete block and brick De Beque School located at the north edge of town near the base of the hills.

Ground motion at this location is at a level where minor damage may be noted in plaster walls and brick and block two-story buildings.

Vega Dam

Vega Dam is an earth dam located about 25 kilometers southeast of GZ. It has a height of 150 feet, a length of 1,950 and storage capacity for 33,800 acre-feet of water. The water level was low and the lake was frozen during the visit; however the lake should be full at shot time. There are many summer cabins in the area around the lake, generally of wood construction.

The safety of the dam is discussed in another section of this report. Ground motion is predicted to be rather low and damage to the summer cabins is not considered probable.

Silt

Silt is a small town located east of Rifle and approximately 30 kilometers from GZ. Structures are generally one-story wood frame buildings with wood or stucco exteriors. Near the highway are several masonry structures which are unoccupied and in poor condition. These masonry structures show evidence of settlement.

Ground motion is predicted to be relatively low. Minor damage to stressed plaster or stucco surfaces is possible and some slight extension of masonry cracks may be noted.

Cameo and Palisades

Cameo, located near the end of De Beque Canyon about 45 kilometers southwest of GZ, is the site of a steam power electrical plant owned by Public Service. The plant is not considered to be a hazard at the low levels of predicted ground acceleration and spectral acceleration which are on the order of 1% g and 2% g respectively. However, personnel should be cautioned to avoid high or precarious positions during the event.

At the town of Palisades structures are generally one story with some two-story commercial buildings noted. Motion is somewhat less than the levels at which damage is normally recorded and we therefore would not expect any damage in this area.

Grand Junction

Peak spectral accelerations in Grand Junction are expected to be less than 0.02g, and ground accelerations are predicted at 0.008g. Structures in Grand Junction are generally one or two stories tall. The tallest structure is the 10-story antenna tower attached to the Mountain States Telephone Co. building. Damage is not anticipated at these levels of motion.

The Oil Shale Company of America (TOSCO) Facility

A steel tower at the TOSCO facility 25 kilometers NW of GZ was inspected on March 24 for a structural evaluation. Structural drawings have been requested for a detailed study but not yet received. A preliminary evaluation was conducted, using available data.

The tower is approximately 200 feet high and 50 feet by 50 feet in plan with 9 supporting columns. One tower had had a history of differential settlement. Attempts have been made to correct this situation by applying horizontal forces at the top of the structure by means of "dead men" anchored into the adjacent cliffs

and pulleys attached to the top of the structure supporting suspended dead weights. Some adjustments have also been made at the base of the columns by use of jacks. According to TOSCO management, the differential settlement problem appears to be solved. Differential settlement has apparently slowed or stopped. Some of the reduction in settlement may be due to consolidation of the foundation material.

Using the rough data obtained from the field trip, masses were approximated and a crude structural dynamic analysis was made.

The results from this crude analysis follows:

	Range of Values	
Period (approx.)	1.20 sec	0.83 sec
Max. Allow. Design (x1.33) Base Shear Coeff.	0.018 g	0.036 g
Max. Pred. RULISON Base Shear	0.004 g	0.008 g
Max. Pred. Top Story Accel.	0.007 g	0.013 g

Max. Allowable Design (x 1.33) Base Shear = 60^k
 Max. Predic. RULISON Base Shear = 13^k

From these rough assumptions and calculations, it appears that event-caused motion from RULISON would account for stresses less than 25% of those allowable. Therefore, no special precautions need be made, other than evacuation of the facility because of rockfall hazard.

If and when drawings and other requested structural information are received from TOSCO, accurate calculations can be made.

No analysis of the foundation material was made. The conclusions contained herewith assume a stable foundation.

EARTH STRUCTURE HAZARDS

Introduction

Rock falls will constitute a major earth structure hazard in the area subjected to ground motion by the proposed event. The region is characterized by canyons which have been deeply dissected by the Colorado River and tributary streams, leaving nearly vertical walls bordering the resulting valleys and stream beds.

Mechanics of Slope Failure in the Rulison Area

The geologic section exposed in the canyon walls is a thick sequence of flat-lying interstratified sandstones and clay shales. The sandstones are hard and strong, jointed, thin bedded to massive, and separated by fissile, very thin to thick bedded soft weak clay shale. Slopes exposed by stream action are undercut along the soft clay shale beds which removes support from beneath overlying sandstone beds. Blocks of rock which are bounded by joint surfaces become detached and fall or slide down-slope. The blocks are dislodged by loss of strength of the clay shale through lubrication or wetting from snow melt, or from precipitation and expansion due to freezing. Larger rock masses or pinnacles may collapse. Mass wasting of the clay shale also has taken place in the form of slumps and flows particularly in areas of springs and seeps, thus creating additional sandstone rock fall hazards by removal of lateral confinement and underlying support. Another effect of removal of lateral confinement is the consequent differential settlement and downslope gliding of large detached blocks and masses of sandstone on and into underlying compressible weathered clay shale beds. These sandstone masses and blocks may glide down slope for considerable distances before tilting past their respective centers of gravity and tumbling down the slope surface to the valley floor.

Dip slope failures (failure of layers along the plane slope of the geological formation) of large intact rock masses as well as individual joint bordered blocks are also observed in the area. These failures occur where dip slopes have been undercut by stream action; excavations for buildings, highways, and railroads; and at tunnel portals.

Occurrence of Slope Failures

Conversations with civil engineers of the Denver and Rio Grande Railroad (D&RG RR), local residents, and newspaper reports suggest that the occurrence of rock falls and landslides are largely controlled by temperature and precipitation.

The frequency of slope failures is highest at the time of the fall freeze, lowers slightly throughout the winter, and rises again with the spring thaw. This is followed by a relatively quiet period through the summer until about mid-August when many landslides are triggered by precipitation run-off from cloudburst. The cloudburst season is usually followed by a short period of slope stability until winter storm and ground freezing again starts the cycle.

De Beque Canyon - Rock falls and landslides consisting of large masses of intermixed sandstone blocks and clay shale are a chronic occurrence in De Beque Canyon. These slope failures periodically block portions of Inter State Highway (IS) 70 and the main line of the D&RG RR for a distance of 14 miles along the Colorado River. The canyon starts just west of the town of De Beque and the hazard area extends for 14 miles almost continuously west to a point just east of the town of Palisade. There are no residences in the main portion of the canyon. Two diversion dams are present in the western portion of the canyon. A steam power plant is located at Cameo and several coal mines are operating in the vicinity. There is a network of active and abandoned canals in the western portion of the canyon, and some residences at the



View of De Beque Canyon, Colorado landslide, showing features of slope instability in the canyon. Interstate Highway 70 is shown extending from the lower left-hand-corner across the toe of the slide. The Colorado river is below the highway to the right of center.

The rim rock collapse is believed to have taken place in 1929. The slide continues to be a hazard, as it is a source of rock falls onto the highway and a chronic highway maintenance problem.

canyon mouth between Cameo and Palisade. A restaurant-gas station-garage which operates the year around is located in the vicinity of Cameo. With the exception of the highway, railroad, and canals, the remaining structures are considered to be relatively free from rock fall hazard but could be affected by large landslides or canyon wall collapse. Access to these locations by rail or road could be blocked by rock falls or slides in the canyon.

Plateau Valley - Rock falls are a particular hazard in Plateau Valley along State Highway 65 from the confluence at the Colorado River east to the vicinity of the Mesa road fork with State Highway 330. Several large slump-type landslides and canyon wall collapses have also occurred in this reach of the valley. The eastern half of the area contains a few ranches, several of which could be damaged by rock falls because of their proximity to the valley walls.

The portion of Plateau Valley extending along State Highway 330 to the town of Collbran and beyond to Vega Dam shows evidence of many flow slides and slumps which have taken place in clay shales in and at the base of the valley walls. There are also numerous landslides and block slump areas adjacent to Plateau Creek in the vicinity of Collbran. These have occurred in clay shale bluffs undercut by the creek.

Structures in portions of Plateau Valley east of the fork with State Highway 65 are for the most part relatively free from rock fall hazards. However, a hazard to structures does exist by flooding if Plateau Creek should be dammed by a slump or slide. This has taken place in the past in several localities, and Plateau Creek is currently becoming blocked in one location through natural sliding.

Collbran-Silt Road - An improved county road extends along a tributary valley from Plateau Creek east of Collbran over a

drainage divide north along Snake Creek and Reservoir Creek to the town of Silt which is located on the north side of the Colorado River on Inter State 70 (US 6/24). The area between Plateau Creek and the confluence of Snake Creek and Reservoir Creek contains many slumps and flows, several of which are active. The valley bottom is occupied by ranch houses and summer homes, all of which appeared to be secured for the winter and unoccupied. This area is relatively free from rock falls but subject to flooding from damming of the creek bed by flows and slides. The area north of the confluence of Snake and Reservoir Creeks is relatively free of hazards from slope failures.

Parachute Creek - Rocks falls are frequent along the valley formed by Parachute Creek. The confluence of the Creek with the Colorado River is just east of the town of Grand Valley. The creek extends in a northwest direction through the Roan Cliffs, then turns north to slightly northeast where several forks draining the Roan Plateau join the trunk stream. An extensive oil shale development has been constructed at the confluence of the trunk stream and its various forks. This facility is referred to as TOSCO (The Oil Shale Corp. of America). Rock falls are a constant hazard to personnel and have on several occasions damaged and destroyed company structures.

In addition to slope instability, TOSCO has a cracking tower founded on 5 to 6 feet of compacted fill, which is in turn underlain by about 170 feet of talus. The tower leans out of plumb at the rate of 2 feet per year when operating and about 0.5 feet per year when not in operation (verbal communication, TOSCO Rep.). It is regularly re-plumbed by base adjustment. A specific analysis and evaluation of the problem posed by this structure have been made and reported in a preceeding section.

The Parachute Creek area towards Grand Valley contains ranch houses, several of which could be damaged by rock falls originating on the adjacent canyon slopes.

Inter State 70 from the Grand Hogback Ridge to the Town of Dotsero - Large portions of IS 70 and the D&RG RR from a point 5 miles east of Silt extending east through the town of New Castle and the City of Glenwood Springs to the town of Dotsero, are subject to rock falls, flow and slump type landslides. Rock falls and landslides along bedding planes and joint surfaces are also frequent.

The Roaring Fork River extending for unknown distance south-eastward from its confluence with the Colorado River at Glenwood Springs is subject to similar slope stability problems.

Denver and Rio Grande Railroad (D&RG RR) - In addition to portions of the D&RG RR previously discussed the following locations have been designated by the Division Civil Engineer as chronic landslide and rock falls areas:

- (1) Niger Hill - 6 miles east of De Beque
- (2) Webster Hill - 4 miles west of Rifle. This portion of the track is scheduled for relocation. Construction is to start the early part of May 1969.
- (3) Track which has recently been relocated from the north to the south side of the Colorado River immediately west of Glenwood Springs parallel to IS 70. Maintenance on this relocation is the responsibility of the Bureau of Public Roads for the next 5 years according to the Division Engineer.

Grand Hogback at Rifle Gap and Harvey Gap Dams - Numerous old landslides were noted adjacent to the left abutment at Harvey Gap Dam as well as rock falls and landslides downstream from the facility along the canyon walls southward to the Colorado River Valley. The dam and reservoir do not appear to be in danger based on field observations to date; however, the road and coal mine structures in the canyon through the Grand Hogback are

vulnerable to both rock falls and landsliding. The same observations apply to the road through Rifle Gap, which contains no other structures.

Mine Dumps

Mine dumps and tailings piles in the area are unstable and failing under static loading. Dynamic loading will increase the instability of such dumps and a hazard will be created in downslope areas. We have presumed that such problems properly belong within the scope of the US Bureau of Mines studies in this area.

HYDRAULIC STRUCTURE AND WATER SUPPLY HAZARDS

General

In the present inventory of hydraulic structures in the general project area of the RULISON event, particular attention has been directed to storage dams and reservoirs. Historical evidence indicates that every dam, regardless of size and type, is in some degree a potential hazard to everything below it.

Causes of Dam Failures

The causes of dam failures are both numerous and variable including the following.

- Inadequate spillway.
- Inadequate spillway. Overtopping by flood wave due to failure of dam above.
- Inadequate cut-offs. Porous foundation allowing leakage and erosion under earth dam, and/or sliding in rigid types.
- Faulty construction; material not properly compacted in earth dams; poor construction in masonry dams.
- Inadequate cut-offs around conduits in earth and rock-fill dams.
- Faulty design of section; slopes too steep in earth dams; section too light in masonry dams.
- Inadequate means for stream control during construction.
- Excessive quantities of clay or other classes of fine material.
- Ice pressure or disintegrating effect of.
- Improper operation or inadequate maintenance.
- Burrowing rodents.
- Poor materials, including soluble salts.
- Unstable or structurally weak foundation.
- Conduits through earth or rock-fill dams not properly supported to prevent settlement or failure. Improper location of valves.
- Insufficient provision against erosion from back-wash below dam or spillway.
- Earthquakes.
- Miscellaneous and undetermined.
- Failure of bottom in small water-works reservoirs.
- Dam overtopping by reservoir seiching.

Dam Failures by Structural Types

In a paper by M. C. Hinderlider,* former State Engineer of Colorado, there is presented a summary of 293 dams in the United States and abroad that failed in the period 1799-1931. More recently numerous failures have revived interest in the study of their causes.

The failures referred to above represent various dam types varying in height from 10 to 190. Classification by dam types and number of failures is shown in the following tabulation.

SUMMARY OF TOTAL, PARTIAL, AND INCIPIENT DAM FAILURES
(Period 1799-1931)

<u>Type of Dam</u>	<u>Number of Failures</u>	<u>Percent of Total Failures</u>
Earth Fill	159	54
Rock Fill	12	4
Gravity Masonry	67	23
Single and Multiple-Arch	7	2
Reinforced Concrete	7	2
Timber	17	6
Miscellaneous	24	9
Total	293	100

Earth Dams

The high percentage of earth dam failures, during the period included in the above tabulation, can probably be explained by lack of understanding of the nature of soils in such dams. Until about 1930 the design of earth dams was based almost exclusively on empirical knowledge and consisted largely of adopting the cross-section of successful dams with little regard to differences in the character of soil and foundation conditions and their action under static and dynamic loadings.

*Hinderlider, M. C., "Necessity For and Penalties For Lack of Supervision", Proceedings, American Society of Civil Engineers, Vol. 58, No. 1, pp. 58-41, (January 1932).

Therefore, with regard to earth dams in the project area of the RULISON event constructed before 1930, such structures may be regarded somewhat suspect regarding their ability to resist sizeable seismic induced forces.

An earth structure of considerable size and relatively close to the blast point (34 km) is Harvey Gap Dam discussed in the following section of this report.

Harvey Gap Dam and Reservoir

Harvey Gap Dam and Reservoir, known also as Grass Valley and Grass Valley Antlers, was originally constructed in 1891. The dam was of the earth-fill type 49 feet in height above the foundation with crest length 580 ft.; width of crest 10 ft.; width of base 255 ft.; downstream slope 2:1; and upstream slope 3:1. Original reservoir capacity was 4,000 acre-feet.

The original dam failed in 1895 and was rebuilt in 1909.

In 1921 the dam was rehabilitated and raised to a height of 60 feet with a crest length of about 800 feet. The gross reservoir capacity was increased to 5,058 acre-feet with a high water surface area of 206 acres. The present operator is the Farmers Irrigation Company. On March 6, 1969, the reservoir water level was approximately 10 feet below top of dam and about 1 foot below spillway crest, if header boards are disregarded. The dam and appurtenant works appear to be in poor condition and improperly maintained.

Until the Rifle Gap Dam was completed in 1967, the Harvey Gap Reservoir was the largest development in the immediate area and supplied water for irrigated lands on Harvey Mesa north of the town of Silt.

It is believed that the dam is a potential hazard in its present structural and hydraulic condition and should receive special

and immediate attention, as discussed below.

Condition Survey Recommendations

The preliminary field observation program has indicated that failure of the Harvey Gap Dam by seismically generated impulsive forces is a possibility. Consequently, the following recommendations are offered for special consideration:

- (1) Conduct engineering investigations of the existing condition of the dam.
- (2) Determine the slope stability and related factors of safety of the structure under seismic loadings likely to be induced by the RULISON event.
- (3) Be prepared to reduce the reservoir water level as much as is possible before the date of the nuclear blast if the results of items (1) and (2) indicate the advisability of such action.

Other Dams and Reservoirs

From published data, as well as discussion with appropriate agencies and individuals we are aware of the presence of numerous dams and reservoirs in the area, not accessible because of snow cover and closed roads. These reservoirs are known to be of various sizes, having various purposes, and in unknown conditions and state of repair. These could constitute hazards to some degree, not as great, however, as that presented by the Harvey Gap Dam discussed above.

Our current opinion is that the Rifle Gap and Vega dams are not hazarded by the expected motion. Studies on these structures are not yet completed, however.

Rural Water Supplies

We have been made aware from our contacts with residents during the structural inventory, that RULISON effects on local water

supplies are a major concern to these people. Wells, cisterns, and streams are vital to the livelihood of many residents and any deleterious effects from RULISON, real or imagined, will be an extremely sensitive aspect of the project operations.

The general region of the RULISON event is low in water yield. Although the watershed area represents about 25 percent of the Colorado River Basin in Colorado the average yield is less than 9 percent of the total. As a consequence of this adverse situation the inhabitants of the mesas must store water in cisterns and tanks for their needs. Sources of water are rain, snowmelt, pumped groundwater, and truck delivery.

Numerous cisterns constructed both in rock and alluvium are located in the immediate vicinity (4-10 km) of the shot point. It is believed that the RULISON event may cause damage to some of the cisterns, well pumps, piping, and auxiliary mechanical and electrical equipment within a radius of about 15 kilometers.

SAFETY PRECAUTIONS AND EVACUATION RECOMMENDATIONS

Certain precautionary measures are recommended for locations which will experience strong ground motion or significant structural motion. These precautions are necessarily conservative, to minimize the possibility of injury to persons, and are based on ERC-predicted motions for the maximum credible yield.

Motion predictions out to a radius of 8 kilometers are in excess of 0.30g and we recommend the evacuation of all persons from the area. Bric-a-brac and fragile hanging objects should be removed to a safe status. Gas and electricity should be shut off to preclude the possibility of fire. The evacuation area generally includes structures in the Rulison area and the Grand Valley area south of the river.

In the town of Grand Valley, the Anvil Points Research Station and various small ranches out to a radius of 14 kilometers, we recommend that persons be evacuated from all structures to a distance of two building heights from the structure.

At the Union Carbide Plant east of Rifle we recommend that personnel remain clear of concrete block structures and tanks during the event.

In the town of Rifle and the Collbran area we suggest that students be moved outside during the event. This is based not on the possibility of structural damage but on the strong motion which may be experienced.

Personnel at the Cameo electrical generating plant should be cautioned to avoid high places or precarious positions at the time of the event.

Because of the potential hazards to railroad and highway traffic from rock falls and landslides, it is recommended that IS 70 and the railroad be closed down to traffic in De Beque Canyon and along the Colorado River from the Grand Hogback through Glenwood Springs to Dotsero.

Portions of State Highway 789/13 between the intersection with State Highway 325 north of the town of Rifle and extending northwest to Rio Blanco should also be closed to travel as well as portions of State Highway 82 extending southeast from Glenwood Springs. State Highway 65 in Plateau Valley extending from IS 70 to the intersection of State Highway 330 should also be closed because of the rock fall hazard. Also the canyon portions of the roads from Rifle Gap Dam and Harvey Gap Dam should be closed and coal mines in Harvey Gap evacuated because of the hazard created by Harvey Gap Dam (see the Hydraulic Structures and Water Supply Hazard section). In Parachute Creek, areas in the upper portion of the creek should be evacuated as well as the TOSCO facility, because of rock fall hazard.

Serious consideration should be given to the possibility of minimizing hazards by rescheduling shot time for sometime in mid-summer following the climax of the spring run off and preceding the period of mid and late summer cloudburst activity.

General warnings should be issued to the public concerning the inadvisability of being on high precarious structures such as tall scaffolding during shot time. Contractors with personnel working under such conditions should be particularly alerted. Construction within about 25 kilometers may have to be temporarily halted because of the possibility of deleterious effects on high concrete, etc.

DAMAGE COST PREDICTIONS

General

The following damage predictions are based on experience gained in predicting and evaluating damage resulting from NTS events and offsite events. To date these events have produced negligible offsite damage due mainly to relatively low actual ground motion, great distances to vulnerable structures and the low structural density of the areas surrounding the event.

In the present case we are faced with a relatively high structural and population density with 25 kilometers of Ground Zero (GZ). The Environmental Research Corporation (ERC) predictions of 5% damped Pseudo Relative Response Velocity (PSRV) are also relatively high for the maximum yield of 60 kilotons. The predictions of response (PSRV) from maximum yield are always used in our evaluation of damage to provide an upper limit of damage and to provide an adequate safety factor with regard to the safety of personnel in the area.

Moderate damage is predicted for structures within 12 kilometers where structural response accelerations are predicted to be correspondingly high. The damage effect decreases with increasing distance and with regard for the type of structure.

Damage complaints may be received from distances as far as perceptible motion occurs (generally at ground acceleration level of 0.001g or more).

Predictions are restricted to structural damage repair cost and do not include costs of interrupted service, etc.

Spectral Matrix Method calculations are in process but are not yet completed.

SUMMARY OF DAMAGE PREDICTIONS

(Based on ERC-predicted PSRV at maximum yield of 60.0 kilotons)

<u>Name</u>	<u>Distance & Direction From GZ (km)</u>	<u>Predicted Effect</u>	<u>Estimated Damage x \$1000</u>
Rulison Farms	8(-) N	Moderate damage	63.0
Grand Valley	10 NW	Moderate damage	30.0
Anvil Points	12 N	Moderate to minor damage	15.0
Microwave	14 W	No damage	--
Ranches	14(+) SE	Minor damage	1.0
Union Carbide	18 NE	Minor damage	5.0
Collbran	19 S	Minor damage	2.0
Rifle	20 NE	Minor damage	5.0
De Beque	25 SW	Minor damage	5.0
TOSCO	25 NW	No damage	---
Vega Dam	25 SE	No damage	---
Rifle Gap Dam	30 NE	No damage	---
Silt	30 NE	Minor damage	3.0
Mesa	32 SW	Minor damage	0.3
Harvey Gap Dam	34 NE	No prediction	---
New Castle	40 NE	No damage	---
Glenwood Springs	53 E	No damage	---
Grand Junction	62 SW	No damage	---
Delta	77 S	No damage	---

CONDITION SURVEYS

Based on our structural inventory of the area and the PSRV predictions by ERC we have made a tentative selection of structures to be condition surveyed. The following is a partial listing of locations and the types of structures which are under consideration at that location. Other structures will be surveyed as deemed necessary. Locations will be selected to include a sampling of cisterns.

De Beque:	New school (brick and concrete block) Old school (brick, abandoned 2 story) 100F (wood frame, 2 story) Sinclair garage (concrete block, 1 story)
Grand Valley:	Valley Upholstery (2 buildings-plastered block) U.S. Post Office High School (brick) Residences (block, corner of Railroad and Second)
Rifle:	Moulton Insurance Bldg. (2 story sandstone) Jeep building and adjoining Estes Trucking
Silt:	School (old stone 2 story with plastered exterior) School (new 2 story concrete block) School (old 2 story wood)
Collbran Area:	Congregational Church 100F Hall Plateau Valley School (brick)
Molina:	Post Office and store (masonry)
Close-in-Areas:	On Morrisania Mesa, Holmes Mesa and the Rulison area within 10 kilometers of ground zero there are many ranches with structures of various

types such as log cabins, wood frame stucco or wood covered, concrete block and stone. Representative buildings will be field selected for a condition survey.

Anvil Points: The oil shale research station will have several structures condition surveyed with movement recording wax or paint placed on cracks in concrete block walls and other vulnerable locations.

Grand Junction: City Center Motel (2 story brick)

Glenwood Springs: Village Inn

Delta: Church - NW cor. 7th & Howard

Montrose: Memorial Hospital

Cedaredge: Community Methodist Church

Aspen: Multistory Apartment complex

TOSCO: Oil Shale Cracking Tower

Meeker: Rio Blanco County Courthouse

The map is not available in electronic format.

Please email lm.records@lm.doe.gov to request the map.

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